A STUDY OF HIGH WALL DETERIORATION

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Senior Thesis -- 570

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INTRODUCTION

This report utilizes several characteristics and factors to explain the process of high wall deterioration. Since the investigation is a survey of three different mining sites within a small geographical area, the factors of structure and compositional make-up of the rocks are the same or very similar. This relationship removes one variable from the study. The variables which need to be considered are: 1. the lengths of time the high walls were exposed, 2. the influences of men, 3. the natural weathering conditions such as frost wedging; water erosion; and the water tables.

The following field techniques are a vital part of the investigation, and are used at all three sites. First of all, a general survey is made of the area in question. The next step is to divide the area into two-hundred square foot sections from which one set of samples is collected. Also the following measurements are made: 1. the width of the pit, 2. the thickness of the high wall beds, 3. the angle of the slope of the talus, 4. the length of the slope of the talus, and 5. the height of the high wall. Although the extreme cases of chemical weathering are noted, this study reflects the most common or average weathering characteristics of the section, such as the location and the size of the water table, the evidence of physical weathering upon the high wall, and evidence of past erosion. The effect of plant growth and the condition of the spoil are also considered.

Since each site has its own characteristic thickness for each bed, and since some of the beds are deleted at some sites, refer to cross sections 2, 4, and 6 for the stratigraphic sequences and the thicknesses; also, below is a key for the names of the beds.

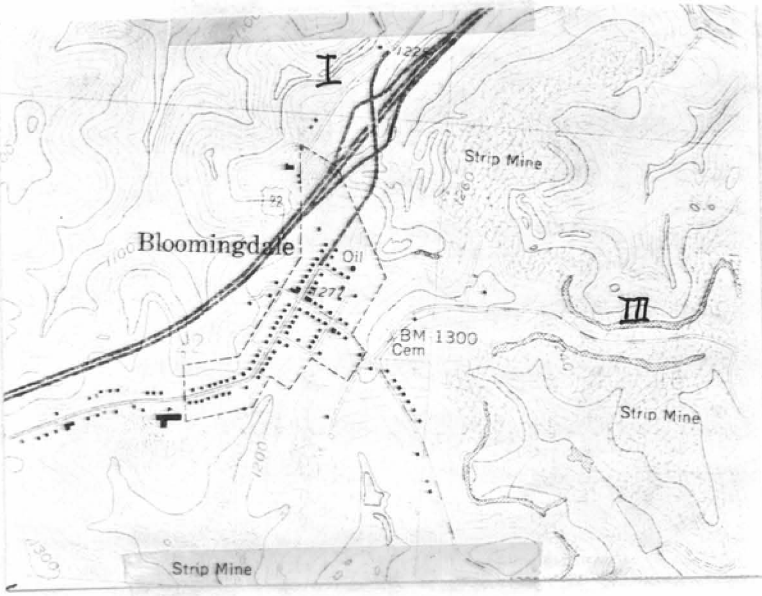
The following chart is a description of the unweathered rock samples obtained from the three sites (Figure 7). They are listed sequentially from the youngest to the oldest:

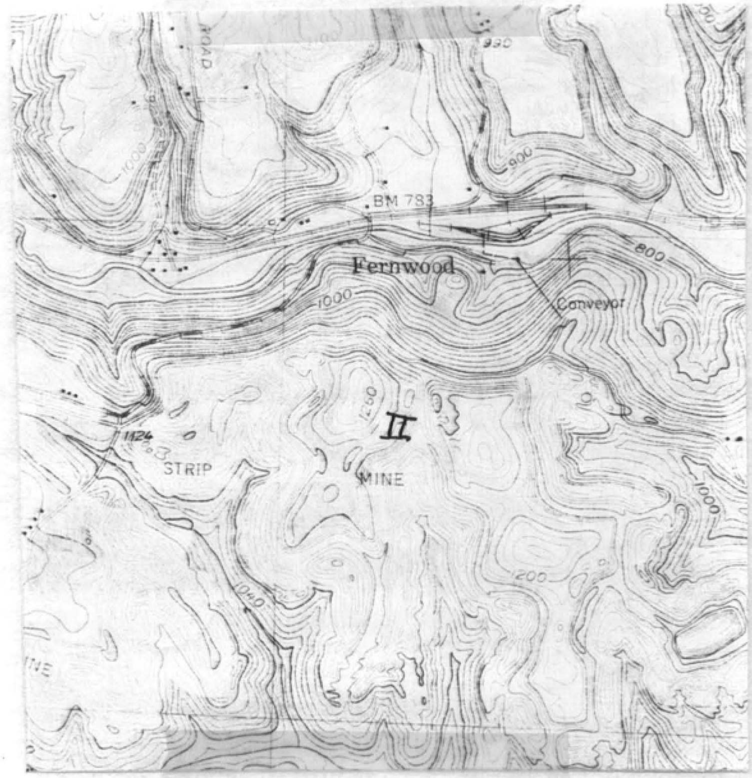
TABLE ONE - GEOLOGIC SECTION FOR STUDY AREA
(after Geological Survey of Ohio, Fourth Series, Bulletin 44, 1943)[1]

	Lower Sewickley sandstone color raw sienna thickness 19' 6"
	Fishpot limestone and marly shale colors violet, ultramarine blue, grass green thickness 20' 1"
Monongahela Formation	Pomeroy coal color black thickness 1' 4"
	Redstone limestone andmarly shale colors carmine red, scarlet red, carmine red with indigo blue dots, scarlet red with indigo blue dots, indigo blue thickness 13' 0"
	Pittsburgh No. 8 coal color black thickness 3' 7"

1 Wilbur Staut, Geological Survey of Ohio, Fourth Series, Bulletin 44, Columbus, Ohio: F.J. Heir Printing Company, 1944, 108.

Fig. 7?
SITES LOCATIONS





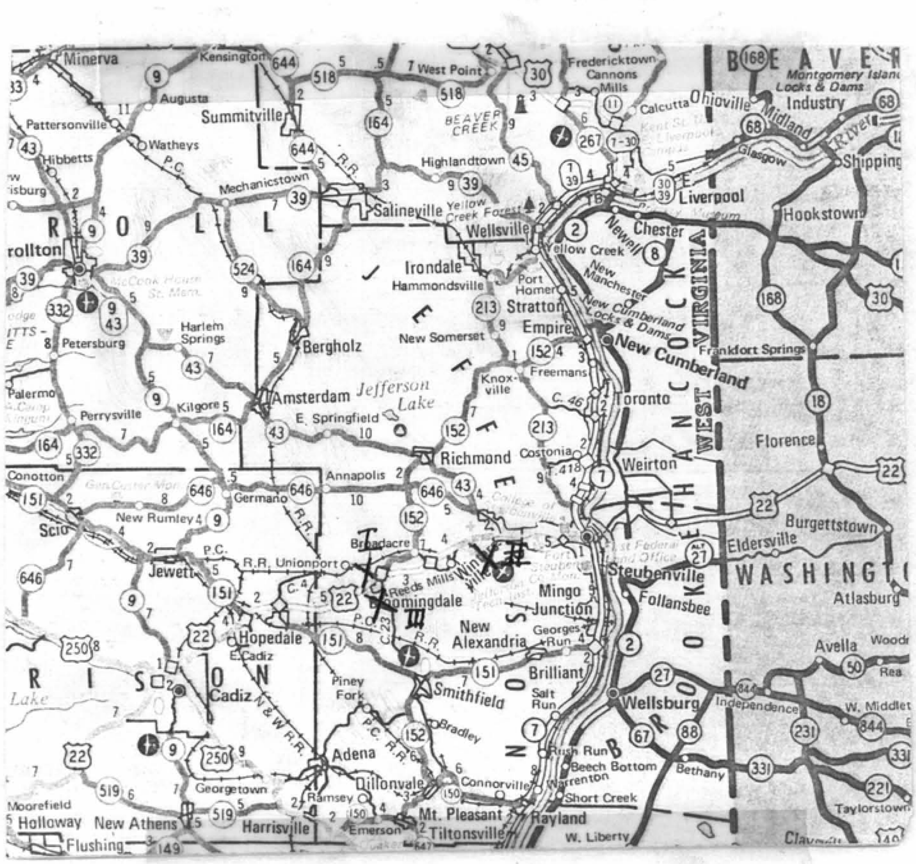


TABLE TWO -- Lithological Characteristics

	Constituents	Color	Characteristics
ss	quartz 95% limonite 1% muscovite 4%	reddish brown to tan	quartz is very finely grained, friable, cemented with limonite; muscovite is fine grained.
sh	quartz 77.5% limonite .5% muscovite 20% carbon 2%	in bands from a grayish black to a blue gray depending upon the composition	the bands vary in thickness from .4 to .5 inches; the muscovite is the same percentage in each layer; the color is due to the varying amounts of carbon at the time of deposition.
lm	calcite 98.5% glauconite 1% limonite .5%	greenish white with patches of tan	uniformly grained throughout; green caused by glauconite; the tan by low or no glauconite or by the presence of limonite.
ss	quartz 93% muscovite 5% glaconite 2%	bluish green	finely grained; cemented by glauconite
sh	quartz 94.5% limonite .5% muscovite 5%	brownish gray	stencil cleavage consistent throughout except in places where sandstone wedges were formed; has the same constituents as the shale except the muscovite concentration ranges from 30% to 40%; thickness is 2" varying to a maximum of 4'5"; length varies from 50' to 150'; the sandstone shows the stencil cleavage due to a high concentration of muscovite.
coal	carbon traces of sulfur & iron oxides.	black	banded in layers from .2" to 2' in thickness.

TABLE TWO --(continued)

	Constituents	Color	Characteristics
lm I	calcite 99% limonite .5% greenish clay .5%	light brown	shows banding parallel to strike and dip of beds plus small cleavage faces; formed by precipitation.
lm II	calcite 99.5% limonite .5%	gray	Calcite nodules with calcite matrix in background; formed by precipitation
lm III	calcite 97.8% clay 1.% limonite .5% shell .3% quartz in clay .4%	light gray with greenish clay in the gray; shells are dark brown	minute crystals are visible; nodules of calcite; formed by precipitation
lm IV	calcite 99.5% limonite .5%	greenish white	brown calcite crystals are .1"x.05"; nodules of calcite 1.53" in diameter; 10% nodules and 5% crystals in a calcite matrix
sh	same as above	same as above	between the layers of limestone is a thin layer of shale, in some cases it is nonexistent; the shale is exactl like the shale above the first layer o coal except the sandstone wedges are not present; there are a few other minor differences in the percentages of the constituents and etc.
sh	quartz 97% carbon 3%	black	stencil cleavage throughout
coal	carbon with traces of sulfur & iron oxides	black	banding of various thicknesses from .2" to 5.5" in thickness.

In all samples, the effects of chemical weathering upon the exposed materials are highly variable depending upon the location of a sample and upon how much of the sample is exposed (example: material sheltered by a protruding high wall ledge as compared to material exposed in the spoil). On the high wall in a vertical location, weathering proceeds at a much slower pace than on the spoil due to the greater exposure of the materials in the spoil.

The chemical weathering of the exposed areas of the high wall is comparable to the chemical weathering of the spoil. The results of the data, which show the amount of chemical weathering taking place, are mixed and variable because they are dependent upon several factors. These factors are: 1. the length of time of the exposure, 2. the original shape of the rock, and 3. the amount of the rock surface exposed. All the given data are for the most extreme cases in order to present a maximum range. All other samples are weathered to a much lesser degree (example: the shale beneath a small amount of iron oxidation as compared to the shale on the spoil which is completely broken down to clay).

The samples used for measuring were hand specimens that were broken up and measured for their distinguishing characteristics.

TABLE THREE -- Site I

Characteristics of Weathered Spoil and High Wall Maturation

sh	shale to a clay of whitish gray color; grainy feeling quartz fragments included
ss	oxidation of the iron for a depth of 9", but evidence of leaching at greater depths in the stone; the muscovite is completely removed for 1.5" then oxidized for 2"; then it is fresh and unweathered; the surface of the weathered stone is friable due to the oxidation and weathering of the surface.
coal	small amount of leaching of sulfur oxides is evidenced by the white streaks; the leaching of iron oxides is shown by the yellow streaks on the outer surface of the coal.
lm I	9" rind and then thin brown layer .4" in thickness; then dark gray core; this case covers the entire sample; interior caused by oxidation of iron oxides and their leaching out on the outer layer; the bands are unchanged in the gray, but are destroyed in the brown to yellow layers; then become planes of stress for the breakdown of the rock.
lm II	yellow exterior of 15" than a dark brown layer for 6.5" to a small core which grades into another core of brown due to the alteration of iron oxides; some of the nodules decomposed; some are decomposing 5" from the surface and some are unchanged one inch or less from the rind.
lm III	a golden yellow rind of 1"; a yellow brown layer .8" in thickness which is clean cut and alters to 3" of gray, then to unaltered rock; the nodules change to brown-tan near the edge of the gray layer which gets darker as it passes through the yellow brown layer; then in the yellow it is totally bleached to a white; the crystals are unaltered until the yellow layer and are removed as are the iron oxides by leaching.
lm IV	a golden .05" rind; then a golden yellow .4" rind; then a brownish tan layer of .85"; then a tannish gray bleeding into a gray; the entire exposed sample is like this with the brown crystals unaffected except on the surface where they are removed by solution; the tannish layer and outer rind are formed by the limonite oxidation and final leaching of iron oxides; the nodules are affected in the same ways as the rest of the rock.
sh	weathered from a black to a gray

TABLE THREE -- SITE II

Characteristics of Weathered Spoil and High Wall Maturation

ss	a leaching of the glauconite to a very pale green throughout the exposed sandstone; the stone is very friable due to the leaching out of the cement
sh	highly iron oxidized; shows leaching out of the limonite; in the spoil, it is broken down into a lumpy clay with shale fragments included
coal	a little leaching of sulfur and iron oxidation is shown by white streaks and yellow streaks on the surface; shows little or no weathering
lm I	a yellow rind of .5" and then a brown layer .3" and then a gray core; the yellow and brown colorings are due to the oxidation and leaching of iron: the bands are unchanged in the gray, but are destroyed in the brown and yellow
lm II	yellow exterior of .05", then a dark brown for 1.5", then a core of unaltered material; the coloration is due to the leaching and oxidation of iron oxides; the nodules are decomposed in the brown; nodules decomposed only in the surface of the yellow layer
lm III	a golden yellow rind of .25", then a yellow brown layer of .3", then an altered gray for 2", then unaltered rock; the nodules are changed to brownish tan near the edge of the gray layer which gets darker as it passes through the yellow brown layer; in the yellow layer they are completely leached to a white; the crystals are unaltered until the yellow layer where they are removed as are the iron oxides by leaching
lm IV	a .75" golden yellow rind, then a brownish tan layer of .32", then a gray; the brown crystals are unaffected until the surface is reached where they are dissolved; the golden yellow and brownish tan colors are formed by oxidation of iron and its removal by leaching; the nodules are affected in the same way as the rest of the rock.
sh	weathered from black to a lumpy gray clay

TABLE THREE -- SITE III

Characteristics of Weathered Spoil and High Wall Maturation

ss	a dark reddish brown where it is exposed due to the oxidation of the iron; the surface is very friable where the iron oxides have been leached away.
sh	the muscovite shows a little breakdown where it is exposed; the shale shows a rich iron oxidation; leaching is shown by stress on the outside surface
lm	a thin layer of yellow oxidation caused by the leaching of iron oxides
ss	for the first .25" it is very friable; then shows a small amount of leaching of the glaconite for .8"; then fresh rock
sh	shows iron oxidation and leaching; it is quite soft almost to the point of being pliable; there is some alteration to clay shown
lm I,II,III, & IV	a yellow coloration on the surface due to iron oxidation and its leaching
sh	shows signs of clay formation; very soft; pliable in some cases

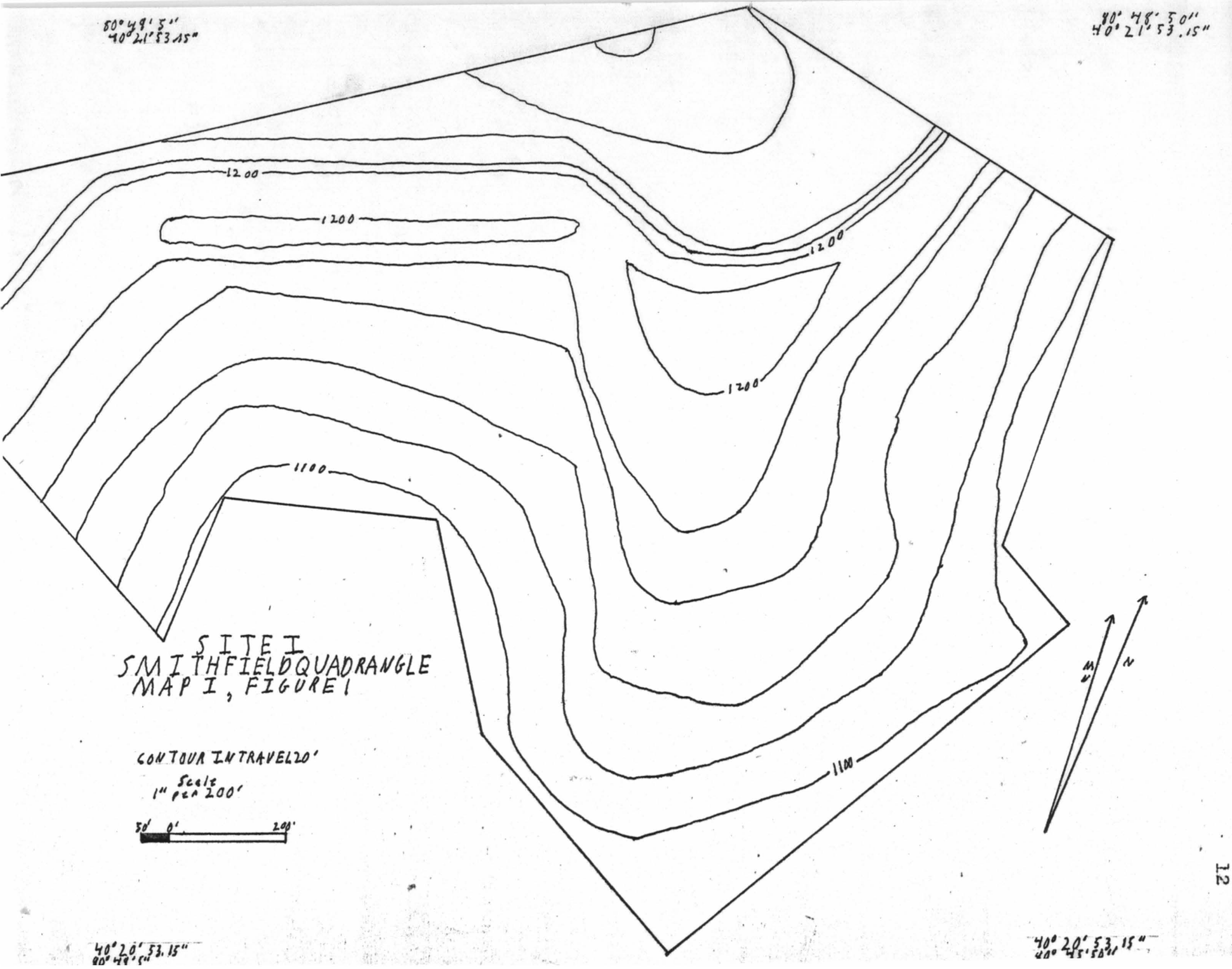
Site I, located in the Smithfield Quadrangle one thousand feet north of the eastern corporation limit of Bloomingdale, Jefferson County, Ohio, (Fig 1); was mined in 1940, by the former Dye Coal company of Cadiz, Ohio. The pit dimensions are forty-five to fifty feet wide and have a length of twenty-two hundred feet. The heights of the high walls range from forty-five to fifty-four feet.

The mining method was by diesel powered shovels after the area had been drilled by a horizontal drill and blasted. The blasting was accomplished by drilling into the hillside beneath the layer of rock to be removed. The blasting charges were placed within the drilled holes and detonated. The blast usually fractured the overlying rock layer, but most of the explosive force was absorbed by the weaker underlying rock. This caused the upper rock layer to break into large pieces which were at times too large for shovel removal. Some of these large pieces are still evident in the pit.

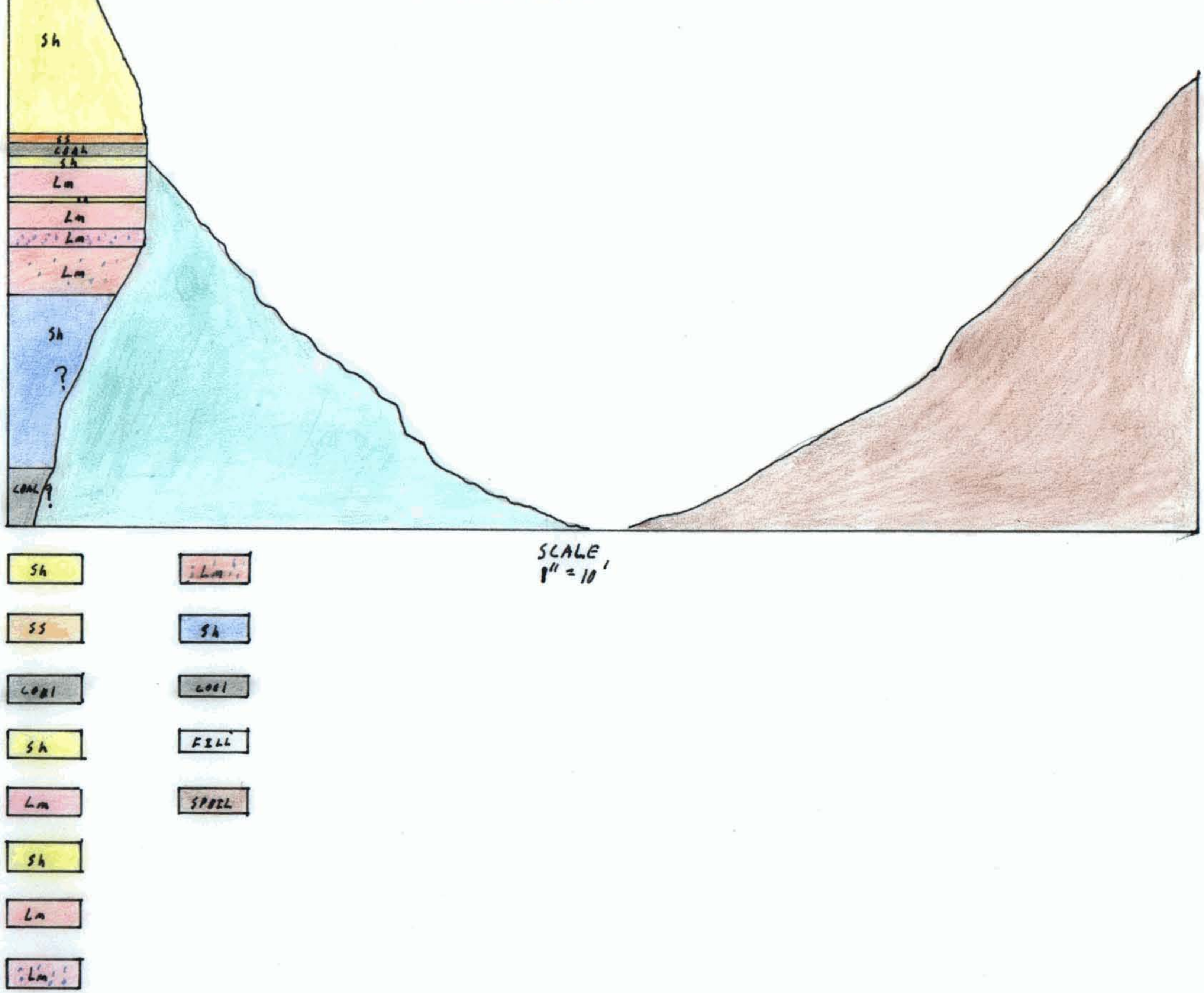
Because of its size, the shovel could not remove more than fifty-five feet of overburden, and it was limited in the placement of the spoil. (This can be seen on the map of site I as the heart shaped mound. The shovel operator used the machine's bucket to shove the spoil and formed the unusually shaped mound).

The undermining of the high wall as shown in the cross section (Figure 2) seems to be a common practice. The shale above the coal was removed in order to excavate the coal beneath it. The supporting evidence is the large amount of limestone fragments contained in the spoil which encroaches into the pit. An interview with Harlan Rulong, a Bloomingdale miner who was employed at this site, confirmed the undermining of the high wall and revealed that the spoils encroach the pit due to the lack of spoiling space. The shovel operator was forced to place the spoil into gentle slopes leading into the pit. These slopes were easily stabilized and added very little to the debris found in the mining pit. This debris then collected inside the pit is a result of the high wall deterioration.

The use of the horizontal drill and blasting contributed greatly to the high wall deterioration by fracturing and weakening the remaining rock layers. Also, the undermining of the high wall further weakened its stability. These weaknesses were then acted upon by the weathering processes to cause more deterioration. Both the mining practices and the weathering processes have affected the high wall deterioration at this mining site.


80°49'5"
40°21'53.15"
80°48'50"
40°21'53.15"
1200
1200
1200
1200
1100
1100
SITE I
SMITHFIELD QUADRANGLE
MAP I, FIGURE I
CONTOUR INTRAVEL 20'
Scale
1" per 200'
50' 0' 200'
M
N
N
40°20'53.15"
40°20'53.15"

SITE I
FIGURE 2



Site II (locationshown on Map 2, Figure 3) was mined in 1954 by the North American Coal Company, Betsy Mine, Smithfield, Ohio. The width of the pit is sixty-five to seventy feet and the length is two thousand three hundred feet with high walls attaining heights of fifty-five to sixty feet.

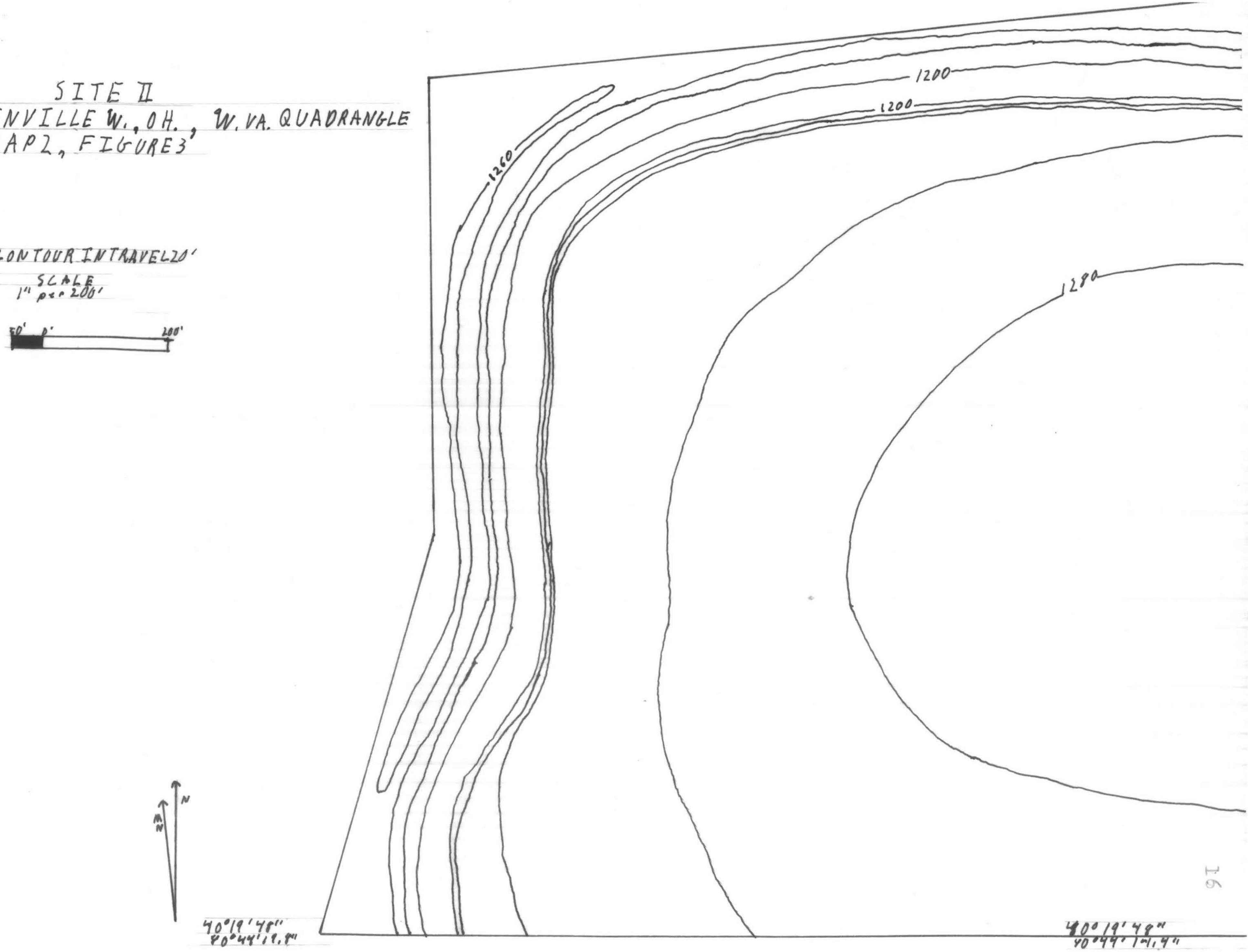
The mining method was to drill vertical holes into the area, load the holes with explosives, and detonate them. This blasting fractured the overlying rock layers. An electrically powered dragline removed most of this fractured overburden, and dug a pit approximately a hundred feet in width. Following the dragline, an electrically powered shovel completed the task of removing the overburden. This machine deposited its spoils in the pit and greatly reduced the pit's width. It also formed a stabilized spoil along the pit's edge. Another smaller shovel, called a loading shovel, excavated the bared coal and loaded it into trucks for shipment. The last machine to enter the pit was called a coal mole. Its task was to auger the coal from under the high wall for a depth of two hundred fifty feet. These auger holes were spaced approximately eighteen inches apart in order to leave pillars to stabilize the high wall.

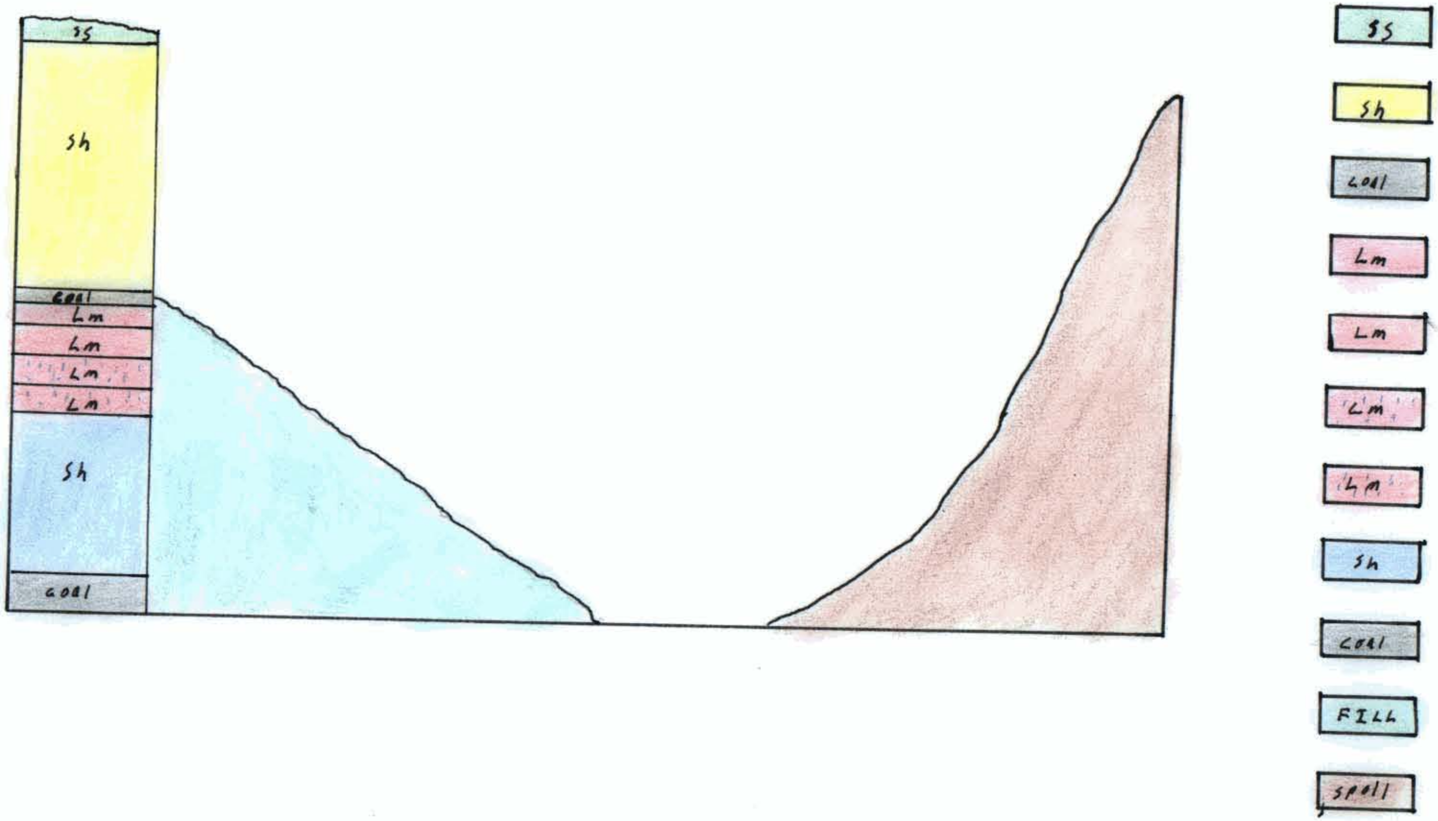
In 1973, a road was constructed by leveling and pushing part of the spoil into the pit. This disestablished the spoil and ruined the source of data on the amount of spoil which had slumped back into the pit.

There is strong evidence that the blasting of the overburden fractured the rock layers for a depth of approximately two feet from the face of the high wall. This conclusion is based upon the fact that the materials are fractured into softball sized pieces and upon the fact that the entire face of the high wall is affected. Physical weathering would not cause these same effects.

SITE II
STEUBENVILLE W., OH., W. VA. QUADRANGLE
MAP 2, FIGURE 3

CONTOUR INTRAVEL 20'
SCALE
1" per 200'





SITE II
FIGURE IV
SCALE 1"=20'

Site III (located on Map 3, Figure 5) was mined in 1963 by the North American Coal Company, Betsy Mine, Smithfield, Ohio. The dimensions of the pit are eighty to ninety feet wide, two thousand two hundred feet long with high wall heights of eighty to eighty-five feet.

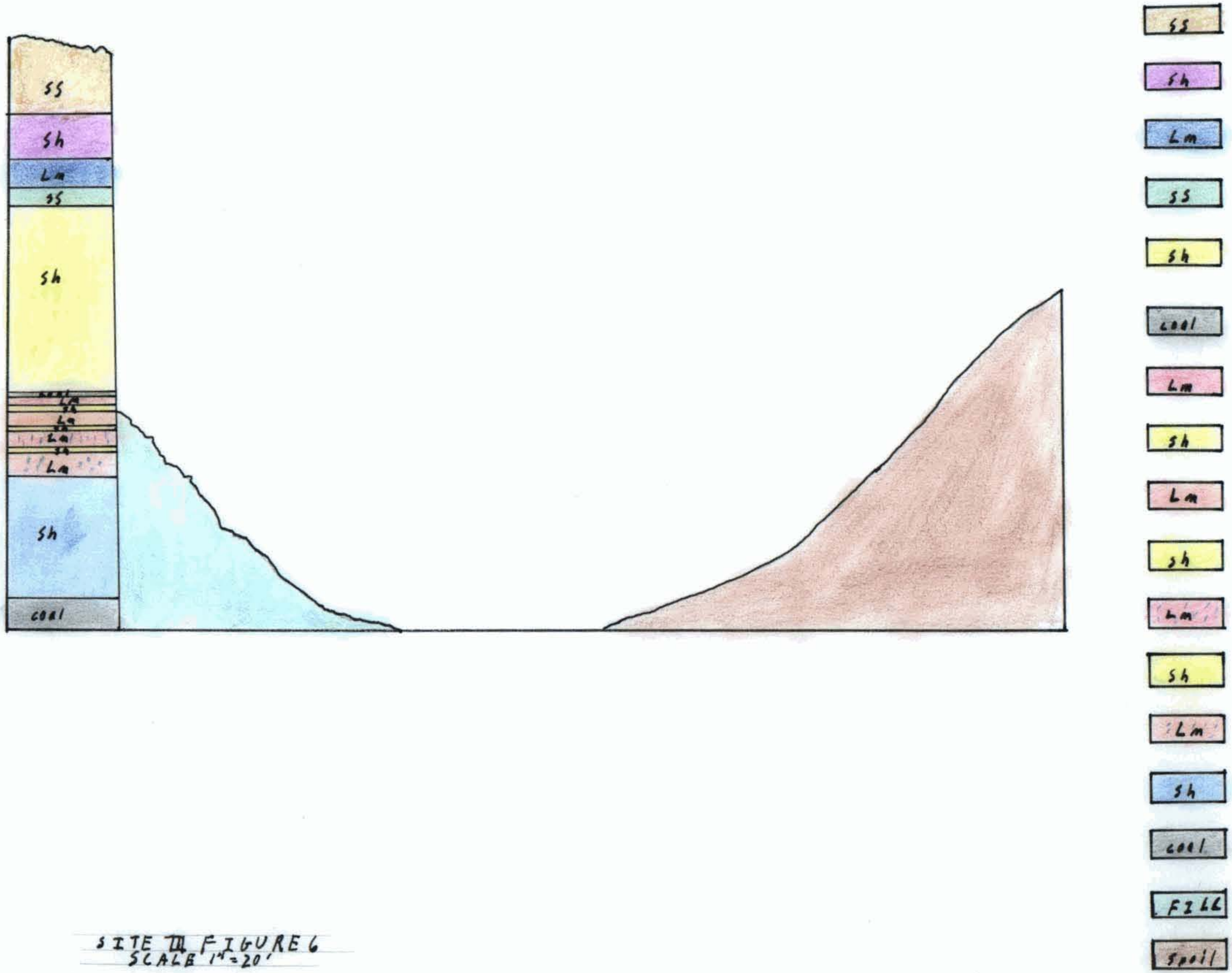
The mining method was the same as for Site II except for one important difference. Although the area was blasted for the removal of the overburden by both the dragline and the shovel, the shovel was unable to operate successfully because of the height of the high wall. From the face of the high wall, fifteen to twenty feet of blasted overburden remains which was undermined by augering. Therefore, a very unstable high wall existed.

After completing the mining processes, the coal company rounded off the spoil into flat-topped hills which were reclaimed by planting young trees and grass. So the spoil factor of refilling the mining pit can be considered as nearly negligible or very minor.

SITE III
SMITHFIELD QUADRANGLE
MAP3, FIGURE5

CONTOUR INTRAVEL 20'

SCALE
0 1" equals 200' 300



SITE III FIGURE 6
SCALE 1" = 20'

Physical weathering is the major influence in the destruction of high walls and in the accumulation of debris in the pit. Some of the factors of physical weathering are: 1. mass movement of materials; 2. gravity, a strong force considering that surface movement is vertical; 3. frost wedging, another strong force due to the expansion of water in cracks which were formed by previous frost wedging, blasting, or internal stress caused by chemical weathering, and; 4. erosion, the physical carrying of material from the high wall.

These seem to be the major factors which deteriorate high walls.

The calculation of the rate of the material flow from the high wall into the pit is accomplished through the ~~deterioration~~ determination of the debris in the pit. There are several assumptions that are made: 1. the high wall is vertical in all places, 2. the same rate of deterioration is occurring at all times, and 3. there were no outside influences acting upon the high walls since their creation.

The equation used in the calculations to determine the number of cubic feet of materials deposited in the pit per year from the high wall utilized the following measurements: 1. the angle of the talus slope, 2. the length of the slope measured along the slope of the talus formation, 3. the length of the area to be calculated measured parallel to the highwall, 4. the number of years the high wall was exposed and the constant number two, and 5. for comparison usage, a standard length of measurement should be used for the length that was measured parallel to the high wall in order to make a comparison of the data among the sites.

Equation: (length of the talus slope) (cosine of the angle of the talus slope) (the length of the area to be measured parallel to the high wall) (the length of the slope of the talus) (sine of the angle of the talus slope) ÷ 2 X (the number of years the high wall was exposed) = the number of cubic feet of materials deposited in the pit per year from the high wall.

The results of the calculations are shown on Table ~~one~~.

TABLE FOUR

The number of cubic feet of materials deposited in the pit per year from the high wall.

Site I	--	25,677 cubic feet per year
Site II	--	27,224.4 cubic feet per year
Site III	--	22,869 cubic feet per year

The measurements used in calculating the results shown in Table ~~One~~ Four are the average measurements for the site, and a standard length of twenty-one hundred feet was used for the length parallel to the high wall.

In order to use and to compare the data calculated from the equation, a brief description of the site and of the other factors that characterize each site must be taken into consideration.

The study of Site I reveals some evidence of blasting fractures, but there are no large open fractures exposed on the face of the high wall. However, there is strong evidence of water erosion, frost wedging, and mass wasting in the form of slumps.

Site I is located parallel to a long sloping ridge that decreases in elevation toward the northwest, causing considerable surface water runoff. Evidence of this runoff can be seen in the gullies eroded into the capping shale of the exposed sequences. In many places the shale is eroded eight to ten feet,but the average is six feet. This evidence is supplemented by the presence of a shallow water table that provides moisture for frost wedging which reinforces the effects of the surface runoff by losing the shale from the surface of the face. Chemical weathering also plays a major role in the physical weathering by oxidizing and softening the shale.

A factor present at Site I is the differential erosion of shale under and around the sandstone lenses which undermine and isolate large masses of sandstone from the lens shaped bodies inside the shale. These bodies, ranging in size from eight feet by six feet by eleven inches to four feet by three feet by two and one-half feet, move under the influence of gravity or mass wasting.

Another prime factor causing the high wall deterioration is that gravity and the fracturing effects of past blasting influence the overlying limestone to fall into the vacated coal and black shale spaces. There is also evidence of mass wasting or flowage of materials in the shale which caps the high wall in three places. The shale is slumping into the pit. The largest movement is measured to be a two and one-half net slip which, upon examination, shows a line of unweathered shale and physically and chemically weathered shale. The length of this body is thirty feet, and extends six feet up the slope of the hill. The other shale locations are minor.

Site II does present evidence of blasting rebound since all the rocks on the high wall face are shattered into softball sized or smaller pieces. This area was studied to a depth of two feet to learn if this fracturing could be caused solely by frost wedging. The conclusion reached is that frost wedging is not the primary reason. The fracturing is too extensive and involves all the formations.

This high wall has massive slumps along the length of the area with exposed fractures eating across the shale above the *rooster vein and the capping sandstone. The largest fracture is two and eight-tenths feet across at the top, runs vertically twenty-eight feet, and fades into a hairline at the bottom..

*Rooster vein - a local mining term referring to a thin seam of coal, which is part of Pittsburgh No. 8 seam, lying 28' above the main bed.

Its horizontal length is seventy feet and fades into hairlines. These massive movements, resulting in this large fracture, are likely caused by the influences of gravity and frost wedging.

The water table does not directly affect the face of the high wall at this site. The level of the perched water table rests atop the *fifty-eight foot lmestone layer farther up the hill above the high wall face. However, indirectly, the water table does affect the high wall because its springs and wet weather springs are a source of surface water runoff.

Site III is very unusual. Four hundred feet west of its position is another parallel high wall and pit that was mined at the same time. This occurred because the coal company was not permitted to dig out the county road bisecting the area. Therefore, the road was left intact atop two high wall faces. As a result, the amount of surface water runoff and the effects of the water table upon Site III are greatly reduced. However, during the winter there were signs (ice and icicles) of the water table influencing the high wall above the fifty-eight foot limestone.

The history of this site mentioned the unstable condition of the high wall due to its incomplete mining processes. However, this instability has not caused large slumps of materials or the movements of large bodies of materials. In the pit, there are only a few boulders which once were part of the capping sandstone. The largest fractures are four to five inches wide and do not cut across bedrock. They are internal. Site III is highly

*Fifty-eight foot limestone -- a local mining term referring to a bed of limestone lying 58' above the mineable coal bed.

blasted and fractured, but it has the least amount of material flowage into its pit of the three studied sites.

INTERPRETATION OF THE DATA AND OF THE CALCULATIONS

The process of chemical weathering (Chart 1) shows that it is based almost solely on the amount of time a particular area or formation is exposed for its action to take effect. Whereas, physical weathering seems to have many factors influencing its outcome (Table 1). Due to severe fracturing, Site III must lack some factors that are common to the other sites, and which can be helpful in interpreting the data.

In comparing the influence of water upon the sites, it can be said that Site I and Site II have approximately the same area for surface water runoff, but Site I has the steeper gradient. Site III has the smallest source area for surface runoff, but it has signs of the water table which Site II does not have since Site II's high wall face is below the water table level. This difference can be cancelled due to the surface runoff from the springs above Site II. The water table is greatly reduced at Site III because of the small size of the surface area needed to build up and store water within the ground.

Site I has little evidence of severe blasting and fractures, and yet, it has the second highest amount of material flowage.

Site II shows blasting rebound, but not the deep blasting nor the fracturing of Site III. Site II has the greatest amount of material flowage due to the influence of its surface water runoff and the water table.

Site III, the most unstable site, has the least amount of material flowage, and is the site which is least affected by the water table and surface water runoff.

From the evidence of the gathered data, this study concludes that the primary factors in the deterioration of the high walls and in the flowage of materials are the presence of the water table and the presence of surface water runoff. The effects of blasting and the effects of the other variables are secondary compared to the influences of the water factors.

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